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Using Workers' Compensation Claims Data to Characterize Occupational Injuries in the Commercial Grain Elevator Industry

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Abstract

Workplace injuries in the grain handling industry are common, yet little research has characterized worker injuries in grain elevators across all hazard types. Learning from past injuries is essential for preventing future occurrences, but the lack of injury information for the grain handling industry hinders this effort. The present study addresses this knowledge gap by using data from over 7000 workers' compensation claims reported from 2008 to 2016 by commercial grain handling facilities in the U.S. to characterize injury costs and severity. The total amount paid for each claim was used as a measure of injury severity. The effects of employee age and tenure, cause of injury, and body part injured on the cost of work-related injuries were investigated. Contingency tables were used to classify the variable pairs. The chi-square test and chi-square residuals were employed to evaluate the relationship between the variable pairs and identify the at-risk groups. Results showed that the employee age and tenure, cause of injury, and body part injured have a significant influence on the cost paid for the claim. Several at-risk groups were identified as a result of the analyses. Findings from the study will assist commercial grain elevators in the development of targeted safety interventions and assist grain elevator safety managers in mitigating financial and social losses from occupational injuries.

Keywords

Chi-square test, Contingency tables, Grain elevators, Grain handling, Occupational injuries

Comments

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S. K. Ramaswamy, G. A. Mosher

ABSTRACT. *Workplace injuries in the grain handling industry are common, yet little research has characterized worker injuries in grain elevators across all hazard types. Learning from past injuries is essential for preventing future occurrences, but the lack of injury information for the grain handling industry hinders this effort. The present study addresses this knowledge gap by using data from over 7000 workers' compensation claims reported from 2008 to 2016 by commercial grain handling facilities in the U.S. to characterize injury costs and severity. The total amount paid for each claim was used as a measure of injury severity. The effects of employee age and tenure, cause of injury, and body part injured on the cost of work-related injuries were investigated. Contingency tables were used to classify the variable pairs. The chi-square test and chi-square residuals were employed to evaluate the relationship between the variable pairs and identify the at-risk groups. Results showed that the employee age and tenure, cause of injury, and body part injured have a significant influence on the cost paid for the claim. Several at-risk groups were identified as a result of the analyses. Findings from the study will assist commercial grain elevators in the development of targeted safety interventions and assist grain elevator safety managers in mitigating financial and social losses from occupational injuries.*

Keywords. *Chi-square test, Contingency tables, Grain elevators, Grain handling, Occupational injuries.*

The grain handling industry in the U.S. is a hazardous work environment, with workers in these facilities constantly at risk of severe and life-threatening occupational injuries (Issa et al., 2016a). Common sources of occupational hazards in grain handling facilities include grain dust, grain engulfment, entrapment in confined spaces, slips, falls, trips, equipment-related hazards, and exposure to harmful chemicals and gases (OSHA, 2016; Snyder and Bobick, 1995). Identification and characterization of past safety incidents can drive potential intervention strategies intended to mitigate injury risks (Cohen et al., 2006; Kines et al., 2007; Menckel and Carter, 1985; Verma et al., 2014). However, the majority of past studies investigating injuries and fatalities in grain facilities have focused only on a few safety hazards. This is true even though the hazards in a grain handling facility are plentiful. Some of the safety risks affecting workers in the grain handling industry include exposure to chemicals and gases, electrical hazards, noise hazards due to

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fast-moving machinery (such as conveyors, motors, and augers), slips, trips, and falls, and finally suffocation and engulfment hazards (Van Fleet et al., 2013).

Despite the numerous workplace hazards in the grain handling industry, very few comprehensive studies have examined worker safety across all the hazard categories. Previous research has examined specific hazards and resulting injuries in commercial grain handling environments. For example, Freeman et al. (1998) examined entrapments in various bulk commodities at commercial grain facilities. Similarly, Field et al. (2014) examined hazards associated with grain vacuum systems at commercial grain storage facilities. No recent comprehensive characterization of injuries in commercial grain handling has been completed. A National Institute for Occupational Safety and Health (NIOSH) study (NIOSH, 1983) was the last time a detailed analysis of injuries in grain elevators was conducted. A review of recent literature showed that very few follow-up studies to the 1983 NIOSH study were completed, even though the grain handling industry has experienced several changes over the last few years (Rosentrater and Williams, 2004).

The grain handling industry plays an important role in U.S. agriculture by storing, distributing, and processing a variety of agricultural commodities (Williams and Rosentrater, 2004). According to the USDA National Agricultural Statistics Service, in 2015, there were 8,638 commercial grain facilities in the U.S., storing and handling 11 billion bushels of grains such as corn, wheat, soybean, and oats. In the last five years, the grain storage capacity in the U.S. has increased by 15%, while the number of grain storage facilities has decreased by 4% (NASS, 2011, 2016). Furthermore, from 2010 to 2015, the average amount of grain stored at each facility increased by 22%. These numbers suggest that U.S. grain handling facilities are getting larger and handling larger volumes of grain than in previous years. This expansion of the grain handling industry has resulted in a high rate of occupational injuries and fatalities as compared to previous years (Riedel and Field, 2011). According to NIOSH, grain-handling machinery is the second largest factor in farm machinery-related deaths and disabilities (Snyder and Bobick, 1995).

The availability of injury data, especially non-fatal injury data, is a continuing challenge. This lack of data limits any potential development of research-based safety interventions in grain handling facilities (Issa et al., 2016a, 2016b; Patel et al., 2016; Zhou and Roseman, 1994). Although Occupational Safety and Health Administration (OSHA) Standard 29 CFR 1910.272 regulates the grain handling industry, OSHA record-keeping does not always include injuries and fatalities that occur in the grain industry (Issa et al., 2016b). Furthermore, many grain handling facilities are exempt from OSHA record-keeping requirements because they have fewer than 11 employees (Douphrate et al., 2006; Zhou and Roseman, 1994). Even in larger facilities, because of budgetary, administrative, and logistical constraints, OSHA collects data only from employers deemed as high hazard, and most often, only from companies with more than 40 employees (Leeth, 2012). Additionally, data gathered from grain handling facilities is frequently mixed with other farm-level data, so drawing conclusions about the workplace conditions of grain elevators becomes difficult (Douphrate et al., 2009b).

The most widely used sources for investigating occupational injuries and fatalities across various industries are the Census of Fatal Occupational Injuries (CFOI) and the Survey of Occupational Injuries and Illness (SOII) published by the U.S. Bureau of Labor Statistics (BLS) (Biddle and Marsh, 2002; Nanda et al., 2016). Waehrer et al. (2007) investigated the cost of occupational injuries in the high-hazard construction industry using SOII data from BLS. Similarly, Asfaw et al. (2011) investigated workplace injuries across five industry sectors using SOII non-fatal injury data. While the BLS data are a useful source for injury investigations, researchers have also highlighted the data's limitations for studying workplace injuries in the agricultural industry (Douphrate et al., 2009b; Landsteiner et al., 2015; Patel et al., 2016; Riedel and Field, 2013). According to Riedel and Field (2013), BLS data include only annual totals for injuries and fatalities and do not provide detailed information, such as causative factors, that is considered essential for studying workplace hazards. Furthermore, evidence from the scientific literature suggests that BLS data significantly underreport work-related injuries, missing between 61% and 88% of non-fatal injuries (Boden and Ozonoff, 2008; Leigh et al., 2004, 2014; Rosenman et al., 2006). For these reasons, a need exists for an alternative injury data source to investigate workplace injuries in the grain handling industry.

Records of workers' compensation insurance claims can partially address the informational gap in occupational injuries in the grain handling industry, enhancing the ability of companies to develop effective safety interventions (Utterback et al., 2014). Workers' compensation insurance provides injured workers with medical benefits, a portion of the employee's wage, and a lump sum payment when the employee suffers a permanent impairment (Sengupta et al., 2012). Employers in all states in the U.S. except Texas are required to provide their employees with workers' compensation insurance. Each year, companies across all industries in the U.S. spend approximately $85 billion on workers' compensation insurance costs (Sengupta et al., 2012; Utterback and Schnorr, 2010). In addition to providing benefits to injured workers, workers' compensation insurance also protects employers from lawsuits resulting from occupational injuries.

Workers' compensation claims contain valuable information commonly used in injury characterization (Utterback et al., 2012). In addition to information on the direct costs of the injury (such as medical, indemnity, and disability payments), data on the industry, occupation, nature of the injury, cause of the injury, and demographic information on the injured worker are also captured in workers' compensation claims (Nestoriak and Pierce, 2009; Utterback et al., 2012). Several studies have highlighted the use of workers' compensation claims as an excellent data source that provides information on workplace injuries and their contributing factors (Dement et al., 2004; Foley et al., 2013; Meyers et al., 2013). The size and volume of workers' compensation datasets provide a comprehensive understanding of injury patterns, which can then be used to analyze the causal factors leading to an injury (Oleinick and Zaidman, 2004).

Previous research has shown that workers' compensation claims data can be used to characterize the risk, scope, and nature of workplace injuries across multiple industries. Neuhauser et al. (2013) used workers' compensation data to compare injury incidence by gender and age while controlling for the occupation and type of industry of the injured worker. Sears et al. (2013) used workers' compensation data to predict occupational disability and medical cost outcomes. Smith et al. (2012) compared risk factors associated with severe versus less severe occupational injuries using workers' compensation data in industries such as agriculture, mining, and manufacturing. Coleman and Kerkering (2007) studied occupational injuries in coal mines and used workers' compensation data to distinguish between lower and higher risk operations and time periods. Schwatka et al. (2013) studied the relationship between age and injury type on claim amount in the construction industry using workers' compensation claims from 1998 to 2008.

Review of the literature also showed that workers' compensation claims data have been used previously to characterize occupational injuries in some agricultural-based industries.

For example, Bell and Helmkamp (2003) examined workers' compensation claims to investigate patterns and rates of non-fatal logging injuries. Douphrate et al. (2009a) studied tractor-related injuries by analyzing workers' compensation data. Similarly, Bookman (2012) used workers' compensation data to investigate occupational injuries among Ohio agricultural workers over a ten-year period (1999-2008). Despite the validated benefits of using workers' compensation data for studying agricultural injuries, limited research has expanded the use of these data to study occupational injuries in the grain handling industry.

This study investigated occupational injuries in grain elevators using workers' compensation claims data provided by a leading Midwest-based insurance company. The purpose of this study was to characterize the direct cost of occupational injuries in the commercial grain industry using information obtained from the workers' compensation claims, including variables such as body part injured, cause of injury, employee age, and employee tenure. A secondary purpose of the study was to identify and classify at-risk groups within the grain handling industry to enable development of targeted intervention strategies for mitigating the risk of occupational injuries.

Methodology

The dataset used in this study was obtained from a private insurance company headquartered in a Midwestern state. A total of 7404 claims dated from January 2008 to March 2016 were analyzed in this study. The variables used in this research, shown in table 1, were taken from the dataset, with the exception of employee age and employee tenure. The age of the injured employee was calculated as the difference between the date of birth and the injury date. Similarly, the tenure of the employee was calculated as the difference between the date of hire and the injury date. Based on input from the insurance company that provided the data and to simplify the analysis, the claim amounts were categorized as: less than \$3,000, \$3,000 to \$9,999, and more than \$10,000.

Grain elevators are classified as off-farm commercial enterprises and are required to provide workers' compensation insurance to their employees (AgWeb, 2015). Employers provide this benefit to their employees by either purchasing insurance from an insurance

Table 1. List of variables in dataset.

No.	Column	Description
1	Claim number	Unique identifier for each claim record
2	Effective year	Filing year of the claim
3	Account	Unique identifier to differentiate claims for each customer
4	Market	Type of business (grain elevator)
5	Gender	Gender of injured worker
6	State	Name of state where injury occurred
7	Date of birth	Date of birth of injured worker
8	Date of hire	Date on which the present company hired the injured worker
9	Injury date	Date on which the injury occurred
10	Claim description	One-line account of incident resulting in injury, e.g., "Employee was cleaning equipment and opened up a line, and acid sprayed in his face and mouth."
11	Claim status	If the claim is still open or closed
12	Body part	Body part(s) injured
13	Cause of injury	Main cause of injury, e.g., "Cut, puncture, or scrape", "heat or cold exposures", "Fall, slip, or trip", etc.
14	Nature of injury	Describes the type of injury, such as fracture, strain, contusion, etc.
15	Claim amount	Total amount paid in medical, indemnity and other miscellaneous payments. Used as a proxy for injury severity in this study.

carrier or through self-insurance (Reville et al., 2001b). When an employee is injured on the job, the insurance carrier or the self-insured employer pays the medical and indemnity costs. To provide information and to facilitate the payment, employers must create a report of the worker's injury to inform their insurance provider (Utterback et al., 2012). Data collected during the claims process are provided by employees, employers, insurance companies, and other involved parties (Utterback et al., 2014). The collection of information from multiple stakeholders makes claims records an excellent data source for work-related injuries (Dement et al., 2004; Janicak, 2010; Kim et al., 2012; Reville et al., 2001a).

The variables used in this study were categorical. For this reason, the statistical analysis began with the construction of frequency counts, percentages, and contingency tables. The chi-square test was used to validate the hypothesis of independence of the claim amount from the demographic variables (age, tenure) and injury variables (nature of injury, body part injured). This statistical methodology was also used by previous studies investigating injuries in agriculture (Javadi and Rostami, 2007; Karttunen and Rautiainen, 2011; Sprince et al., 2003). Standardized residuals were calculated to identify the source of dependence between the two variables or at-risk groups. The standardized residual is the difference between the observed value of a particular variable and its expected value divided by the standard deviation of the expected value (Agresti and Finlay, 2008). A positive residual implies that the observed value is greater than the expected value, while a negative residual indicates the observed value is less than expected value. The value and sign (positive or negative) of residuals are used to determine the nature of the relationship between the row and column variables of the contingency tables (Lopez et al., 2011).

All descriptive and inferential analyses were performed with SAS software (ver. 9.4, SAS Institute, Inc., Cary, N.C.). In SAS, residuals are standardized and calculated as:

$$\text{Standardized residual} = -\frac{n_{ij} - e_{ij}}{\sqrt{e_{ij}(1-p_i)(1-p_j)}} \tag{1}$$

where n_{ij} is the observed value, $e_{ij} = (n_i * n_{.j})/n)$ is the expected value for the ith row and jth column cell, $p_{i.}$ is the proportion in row ($n_{i.}/n$), and $p_{.j}$ is the proportion in column j ($n_{.j}/n$) (Shoukri and Chaudhary, 2007). According to Agresti and Finlay (2008), an adjusted residual of ±2 is evidence of dependence between the row and column variables, while an adjusted residual of ±3 is evidence of strong dependence. Examining the adjusted residuals of each cell in a contingency table helped identify the at-risk groups, i.e., where the degree of dependence between the two variables was the strongest (Sharpe, 2015).

Because the purpose of this study was to characterize the direct costs of occupational injuries using demographic and injury characteristics, the claim amount was used as a proxy for the direct injury cost. The broad question that guided this study was: Is the claim amount of injuries in grain elevators independent of the employee demographics and injury characteristics? Specifically, the following research questions were analyzed: Is the claim amount independent of: (1) age of employee? (2) tenure of employee? (3) nature of injury? and (4) body part injured?

Results and Discussion

Characterizing Claim Amount Based on Employee Age

The first research question investigated if the claim amount and the age of the injured employee were independent. The claim amount is the sum of all payments made by the workers' compensation insurance provider to the injured employee. This amount includes medical, indemnity, and other miscellaneous payments made to the injured employee as compensation for the work-related injury. For this reason, severe injuries, such as those resulting in disability or death, have a higher claim amount than less severe injuries requiring less medical treatment (Sears et al., 2013, 2014).

To explore the relationship between employee age and claim amount, a contingency table with age as the row variable and claim amount as the column variable was tabulated, as shown in table 2. Each cell in the contingency table is a count of claims corresponding to the respective age group and claim amount category. The last row in table 2 shows the total number of claims in each claim amount category, while the last column indicates the number of claims corresponding to each age group.

Of the 7404 claims, only 7399 had employee age information. The distribution of the number of claims based on the claim amount indicates that nearly 84% were less than $10,000, suggesting that small injury claims are the largest workers' compensation expense for grain handling facilities. The distribution of the number of claims based on age group shows that 50% of the claims involved an employee less than 45 years old, and 76% of the claims involved an employee less than 55 years old. One out of every four claims involved an employee older than 55 years. This result is different from the studies by Douphrate et al. (2009b), Bookman (2012), and Reiner et al. (2016), in which injuries to employees less than 55 years old constituted over 90% of the injuries. One reason for this difference in distribution between the current study and previous studies could be the type of occupation investigated in these studies. For example, Bookman (2012) analyzed workers' compensation claims of employees in various agricultural occupations, such as poultry and egg producers, logging or tree removal, and fisheries and hatcheries. Similarly, Reiner et al. (2016) investigated only farm injuries caused by large machinery, such as augers, balers, and harvesters.

A chi-square test was conducted to evaluate if the claim amount varied based on the age of the employee. The test results showed a p-value of less than 0.05, providing evidence that the claim amount and the employee age were not independent. This finding implies that the claim amount varied based on the age of the employee and that employee age is a significant factor that can be used to determine the claim amount. This finding is consistent

Table 2. Relationship between age of employee and claim amount.[a]

Age Group (years)	Claim Amount <$3000 ($n_{ij}$) (SR)	 $3000-$9999 (n_{ij}) (SR)	 ≥$10,000 ($n_{ij}$) (SR)	Total (n_i) (%)
<25	979 (8.8**)	64 (-2.3*)	82 (-8.6**)	1125 (15.2%)
26-30	636 (5.6**)	45 (-1.4)	67 (-5.5**)	748 (10.1%)
31-35	549 (2.3*)	50 (-2.7*)	84 (0.0)	683 (9.2%)
36-40	503 (0.2)	40 (0.6)	109 (-1.2)	652 (8.8%)
41-45	481 (-2.3*)	51 (0.5)	126 (2.4*)	658 (8.9%)
46-50	608 (-3.0**)	64 (0.4)	165 (3.2**)	837 (11.3%)
51-55	688 (-2.5*)	68 (-0.6)	180 (3.0**)	936 (12.7%)
56-60	652 (-4.0**)	72 (0.7)	188 (4.2**)	912 (12.3%)
60+	585 (-5.7**)	87 (3.5**)	176 (4.1**)	848 (11.5%)
Total (n_j) (%)	5681 (76.8%)	541 (7.3%)	1177 (15.9%)	7399 (100%)

[a] n_{ij} = count in ith row and jth column, (%) = row and column percentages, n_i = row total, and n_j = column total. Residuals are shown in parentheses: * = evidence of relationship; ** = evidence of strong relationship (χ^2 = 180.14; df = 16; p < 0.0001 and α = 0.05; N = 7399).

with previous studies that also found a significant relationship between employee age and injury severity (Laflamme, 1996; Rogers and Wiatrowski, 2005; Salminen, 2004; Takahashi and Miura, 2016). According to Rogers and Wiatrowski (2005) and Salminen (2004), young workers (<25 years old) have a higher risk of injuries than older workers. However, injuries to older workers are likely to be more severe when compared with younger workers. More severe injuries require increased medical attention and could also result in lost workdays, resulting in a higher claim amount.

To identify at-risk age groups, residuals were examined. The residuals indicate a strong relationship between employee age and claim amount across all age groups, except employees 36 to 40 years old. It is noteworthy that as the employee age increases from <25 to 40 years, the sign of the residual indicates a greater than expected number of claims in the <\$3,000 category and fewer than the expected number of claims in the ≥\$10,000 category. This finding implies that employees up to 40 years old are likely to have less severe injuries, which require minimum levels of workers' compensation payments. The residual values for the 41 years and older age groups indicate exactly the opposite of that for the age groups below 40 years. In the 41 years and older age groups, the number of claims in the <\$3,000 category is less than the expected value, while the number of claims in the ≥\$10,000 category is more than the expected value. This finding implies that injuries to grain elevator employees who are older than 40 years are likely to be more severe and expensive as compared to employees who are younger than 40 years. In other words, as the employee age increases, the number of claims for minor injuries tends to decrease. At the same time, as the employee age increases, the number of claims for major injuries tends to increase, suggesting that older employees in grain handling facilities should heighten their focus on safe work practices. In this study, the minor claims for younger employees become more "major" as the employee ages. This finding further corroborates the results of previous studies (Laflamme, 1996; Rogers and Wiatrowski, 2005; Salminen, 2004; Takahashi and Miura, 2016), which suggested that older workers are likely to have more severe injuries than younger workers.

Characterizing Claim Amount Based on Employee Tenure

The second research question investigated if the tenure of the injured employee and the claim amount were independent of each other. The contingency table used to investigate this research question is shown in table 3. Of the 7404 claims, only 7396 had employee tenure information. The distribution of the number of claims by employee tenure indicates that nearly half of all injury-causing incidents involved an employee with two or fewer

Table 3. Relationship between tenure of employee and claim amount.[a]

Employee Tenure (years)	Claim Amount <\$3,000 (n_{ij}) (SR)	\$3000-\$9999 (n_{ij}) (SR)	≥\$10,000 (n_{ij}) (SR)	Total (n_i) (%)
<1	1138 (2.5*)	98 (-0.8)	199 (-2.4*)	1435 (19.4%)
1-2	1641 (3.2**)	147 (-0.4)	281 (-3.4**)	2069 (28.0%)
3-5	1017 (-0.3)	94 (-0.4)	219 (0.6)	1330 (18.0%)
6-10	764 (-2.8*)	76 (0.0)	201 (3.2**)	1041 (14.1%)
11-20	648 (-2.9*)	77 (1.6)	164 (2.2*)	889 (12.0%)
20+	470 (-1.5)	49 (0.4)	113 (1.4)	632 (8.5%)
Total (n_j) (%)	5678 (76.8%)	541 (7.3%)	1177 (15.9%)	7396 (100%)

[a] n_{ij} = count in the ith row and jth column, (%) = row and column percentages, n_i = row total, and n_j = column total. Residuals are shown in parentheses: * = evidence of dependence; ** = evidence of strong dependence (χ^2 = 33.56; df = 10; p = 0.0002 and α = 0.05; N = 7396).

years of work experience. Similarly, 65% of all injury-causing incidents involved an employee with five or fewer years of experience, and 80% of all incidents involved an employee with ten or fewer years of work experience. Furthermore, the general trend of the number of claims by employee tenure indicates that the number of claims decreases as tenure increases. According to Vinodhkumar and Bhasi (2009), the length of service of an employee influences the employee's skills and attitudes toward safety. In their comprehensive study of farm injuries, Mariger et al. (2009) observed that experienced workers in agriculture tend to have fewer injuries than less experienced workers.

The chi-square test to evaluate if the claim amount varied based on employee tenure showed a p-value of less than 0.05, suggesting that the tenure of the injured employee is a significant factor that can be used to determine the claim amount. The relationship between employee tenure and injury severity has not been investigated in the agricultural industry. Evidence from studies conducted in other high-hazard industries, such as construction and petrochemicals, suggests a significant relationship between between employee tenure and injury severity (Cheng et al., 2013; Lopez et al., 2012; Nouri et al., 2008; Suarez-Cebador et al., 2014).

The residual values from the chi-square test show evidence of a relationship between employee tenure and claim amount across most age groups. For claims below $3,000, the residuals change from positive to negative as the employee tenure increases, suggesting that the longer the tenure of an employee, the fewer small claims the employee incurs. The opposite is true for claims above $10,000, with residual values shifting from negative to positive. In this case, the longer the tenure of an employee, the more likely the employee will incur a more expensive workers' compensation claim. This shift in injury severity could be attributed to the age of the employee, because tenure and age are highly correlated (Vinodkumar and Bhasi, 2009). As employee tenure increases, so does employee age, reducing the employee's ability to tolerate injuries (Brorsson, 1989) and thereby increasing the likelihood of severe injuries.

Characterizing Claim Amount Based on Cause of Injury

The third research question investigated if the claim amount was statistically independent of the cause of injury. The contingency table used to classify the claim amount by cause of injury is shown in table 4. The distribution of claims in table 4 revealed that "strain or injured by" was the most common cause of injury, followed by "slip, fall, and trip" and "struck or injured by". Nearly 29% of claims were for strain and sprain injuries, while "heat

Table 4. Relationship between cause of injury and claim amount.[a]

	Claim Amount			
Cause of Injury	<$3,000 ($n_{ij}$) (SR)	$3,000-$9,999 (n_{ij}) (SR)	≥$10,000+ ($n_{ij}$) (SR)	Total (n_i) (%)
Strain or injured by	1552 (-4.3**)	173 (1.8)	387 (3.6**)	2112 (28.5%)
Slip, fall, or trip	1281 (-11.6**)	178 (3.9**)	448 (10.5**)	1907 (25.8%)
Struck or injured by	926 (7.4**)	62 (-2.2*)	94 (-7.0**)	1082 (14.6%)
Others	666 (7.5**)	31 (-3.6**)	63 (-6.1**)	760 (10.3%)
Cut, puncture, or scrape	650 (10.1**)	26 (-3.9**)	30 (-8.9**)	706 (9.5%)
Vehicle	190 (-5.3**)	35 (3.0**)	72 (4.0**)	297 (4.0%)
Heat or cold exposures	246 (3.0**)	13 (-1.9)	34 (-2.1*)	293 (4.0%)
Caught in, under, or between	175 (-2.6*)	23 (1.2)	49 (1.7)	247 (3.3%)
Total (n_j) (%)	5686 (76.8%)	541 (7.3%)	1177 (15.9%)	7404 (100%)

[a] n_{ij} = count in ith row and jth column, (%) = row and column percentages, n_i = row total, and n_j = column total. Residuals are shown in parentheses: * = evidence of dependence; ** = evidence of strong dependence ($\chi^2 = 351.6$; df = 14; $p < 0.001$ and $\alpha = 0.05$; $N = 7404$).

or cold exposures" and "caught in, under, or between" accounted for only 4% of the claims. Furthermore, more than half (54%) of the injuries recorded were either due to "strain or injured by" or to "slip, fall, and trip".

The chi-square test suggested that the claim amount was not independent of the cause of the injury. This finding means that the claim amount is not the same for all type of injuries and that the cause of the injury is a significant factor that can be used to determine the claim amount.

Examining the chi-square residuals indicates that certain injuries are more likely to have higher claim amounts. For example, injuries in the "strain or injured by" and "slip, fall, and trip" categories are likely to be more expensive when compared to the "struck or injured by" and "others" categories. A review of the agricultural safety and health literature shows that strain injuries and slips, trips, and falls are common across many industries, including agriculture (Bobick and Myers, 1994; Davis and Kotowski, 2007; Douphrate, 2008; Fathallah et al., 2008). In the U.S., strain injuries alone cost \$6.5 billion in workers' compensation costs, with the average claim ranging from \$5000 to \$8000 (Baldwin and Butler, 2006; van Tulder et al., 2007).

Residuals from the chi-square test also indicate that the "slip, trip, or fall", "struck or injured by", "others", "cut, puncture, or scrape", and "vehicle" categories have the strongest relationships with claim amount. Evidence of a significant relationship with claim amount was also observed in one cell corresponding to the "caught in, under, or between" category and in two cells corresponding to the "strain or injured by" and "heat or cold exposures" categories. However, the sign of the residuals suggests that the claim amounts are more likely to be ≥\$10,000 and less likely to be <\$3,000 for the "strain or injured by", "slips, falls, or trips", and "vehicles" categories. This finding suggests that injuries due to slips, trips, and falls, injuries involving a strain, and injuries due to vehicles are likely to be more expensive than other types of injuries. For the remaining categories (including "others", "struck or injured by", and "cut, puncture, or scrape"), the residuals indicate that the claim amount is likely to be lower. Based on these analyses, targeting slips, trips, and falls, strain-related injuries, and vehicle-related injuries through safety interventions could potentially reduce the claim amount significantly.

Characterizing Claim Amount Based on Body Part Injured

The final research question investigated if the claim amount was statistically independent of the injured body part. A contingency table constructed to address this research question is shown in table 5. The distribution of data suggests that upper extremities (such as hands and fingers) were the most frequently injured body part, followed by lower extrem-

Table 5. Relationship between body part injured and claim amount.[a]

Body Part Injured	Claim Amount <\$3,000 (n_{ij}) (SR)	\$3,000-\$9,999 (n_{ij}) (SR)	≥\$10,000 (n_{ij}) (SR)	Total (n_i) (%)
Upper extremities	1909 (-2.6*)	182 (-0.4)	454 (3.3**)	2545 (34.4%)
Lower extremities	1178 (-5.2**)	126 (0.7)	331 (5.4**)	1635 (22.1%)
Trunk	1203 (-0.5)	142 (2.9*)	231 (-1.5)	1576 (21.3%)
Head and neck	1071 (11.2**)	58 (-3.6**)	71 (-10.3**)	1200 (16.2%)
Others	325 (-2.2*)	33 (0.0)	90 (2.5*)	448 (6.1%)
Total (n_j) (%)	5686 (76.8%)	541 (7.3%)	1177 (15.9%)	7404 (100%)

[a] n_{ij} = count in ith row and jth column, (%) = row and column percentages, n_i = row total, and n_j = column total. Residuals are shown in parentheses: * = evidence of dependence; ** = evidence of strong dependence (χ^2 = 155.1; df = 8; p < 0.001 and α = 0.05; N = 7404).

ities (such as toes and feet) and trunk. In nearly 80% of the claims, the injured body part was either an upper extremity, trunk, or lower extremity. This finding is different from the results of the NIOSH (1983) study, which reported back, finger, and eyes as the three most injured body parts.

The chi-square test results indicated that the claim amount was not independent of the body part injured. This finding suggests that the claim amount varied based on the body part injured and that the body part injured is a significant factor that can be used to determine the claim amount.

Examining the chi-square residuals indicates that upper extremities, lower extremities, head and neck, and the "others" category show evidence of a relationship with the claim amount. For upper extremities, lower extremities, and the "others" category, the residuals indicate that the number of claims is more likely to be in the ≥$10,000 category and less likely to be in the <$3,000 category. This finding suggests that injuries to upper and lower extremities tend to be more expensive compared to the "head and trunk" and "others" categories. Similarly, for trunk, head, and neck injuries, the residuals indicate that these injuries are more likely to be inexpensive compared with the other categories.

Conclusion

Occupational injuries across all hazard categories of the grain handling industry have received little attention in the research literature. One reason for this is the lack of a centralized source of data to quantify the incidents. This study used workers' compensation claims data to investigate patterns of workplace injuries in the grain handling industry. The first research question examined if the claim amount was independent of the age of the employee. This study found that the employee age had a significant influence on the claim amount. Furthermore, employees who are older than 40 years have a higher likelihood of severe injury than employees who are younger than 40 years.

The second research question investigated if the claim amount was independent of the tenure of the employee. The results showed that the tenure of the employee had a significant influence on the claim amount. In addition, employees with less than five years of work experience were found to be the most at-risk group because the majority of injuries involved employees in this category.

The third research question examined if the claim amount was independent of the cause of injury. The results showed that the cause of injury had a significant influence on the claim amount, suggesting that the injury cost varies based on the cause of injury. This study found that strains and slips, falls, or trips were the most significant causes of injuries.

The final research question investigated if the claim amount was independent of the body part injured. The data showed that the claim amount was significantly related to the body part injured. Injuries to upper and lower extremities, the trunk, and to other body parts have the most influence on claim amount.

While workers' compensation data are extremely useful in injury prevention studies, the recording of information during the workers' compensation claims process could be prone to human error, as the data are collected by field agents. In addition, the scope of analysis is narrowed by the information available in the dataset. For example, the number of hours worked by each of the injured employees was not available in the dataset. Therefore, implicit assumptions (e.g., that the number of hours worked was same for employees in all age and tenure groups) were made in this study. However, the analysis of a large number of claims, recorded over an extended period, characterizes the strength and rigorousness of this study.

The findings of this study will enhance the understanding of recommended areas of preventative intervention in grain handling environments. Future work could involve analyzing the relationships between non-cost-related variables as well as simultaneously investigating all the variables and their interaction effects. A multivariate model of the claim amount could also be constructed so that commercial grain elevators, as well as the workers' compensation insurance providers, can better analyze the risks contributing to occupational injuries.

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